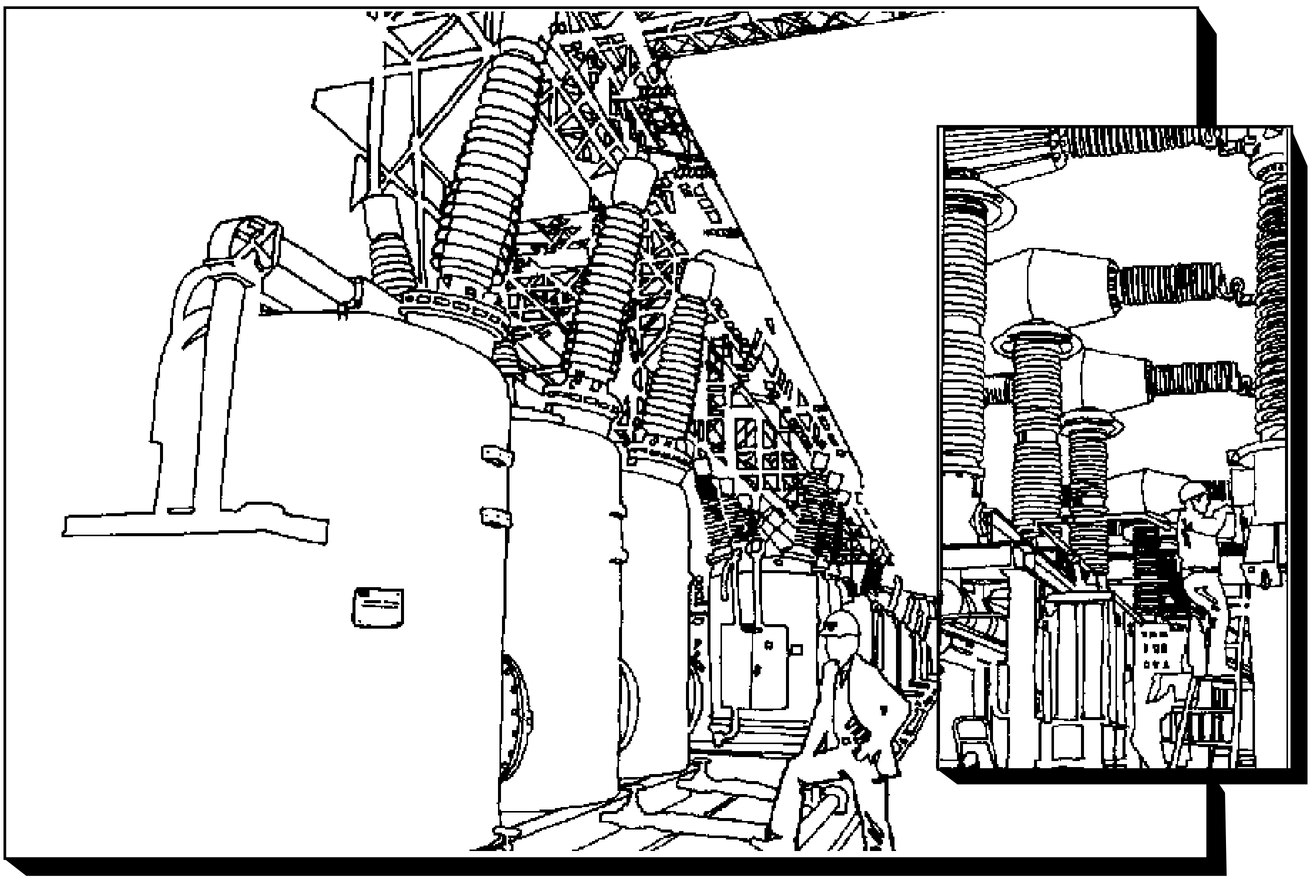
POWER CIRCUIT BREAKER MAINTENANCE



CHAPTER 7

POWER SYSTEM MAINTENANCE MANUAL

JUNE 1998

Western
AREA POWER
ADMINISTRATION

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

POWER CIRCUIT BREAKER MAINTENANCE

JUNE 1998

WESTERN AREA POWER ADMINITSTRATION POWER SYSTEM MAINTENANCE MANUAL

CHAPTER 7

APPROVED FOR PUBLICATION AND DISTRIBUTION
AS A WORKING CHAPTER*

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Date

*To Be Revisited In Approximately One Year

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PREFACE

This guide is issued by the Western Area Power Administration (Western) and is designed to provide specific guidelines, instructions, procedures, and criteria for maintenance performed on all types of circuit breakers. Procedures and guidelines are in accordance with and supplement Western's Power System Safety Manual (PSSM). Corrections and comments concerning this guide may be addressed to:

Western Area Power Administration
Corporate Service Office
Attn: A3940, Technical Support for Maintenance
P.O. Box 3402
Golden, Colorado 80401-0098

PROPOSED REVISION TO POWER SYSTEM MAINTENANCE MANUAL, CHAPTER 7, POWER CIRCUIT BREAKER MAINTENANCE

Type of Revision: Addition, Deletion, Rewording, Other (CIRCLE ONE)	**Section Number:** _______________
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TABLE OF CONTENTS

SECTION **PAGE**

POWER CIRCUIT BREAKER MAINTENANCE

1. SCOPE.

These guidelines and maintenance procedures on maintenance of circuit breakers supplement the requirements of Western Area Power Administration's (Western) Power System Safety Manual (PSSM). In the event of a conflict between this chapter and those contained in the PSSM, the PSSM shall prevail. All Western and contractor maintenance personnel performing maintenance on Western owned power circuit breakers shall comply with these procedures.

2. PURPOSE.

The purpose of this chapter is to establish safe, clear, and consistent guidelines and procedures for the maintenance of Western's power circuit breakers used exclusively for the purpose of power transmission and distribution.

3. DEFINITIONS.

A. **Annual Maintenance.** Operation of the breaker, along with cabinet maintenance, which may include diagnostic testing.

B. **Breaker Monitors.** These devices can monitor various quantities on the breaker and when a predermined setpoint is reached or exceeded gives notification.

C. **Breaker Timing Test.** Circuit breaker motion analyzers are portable devices designed to monitor the operation of power circuit breakers which permit mechanical coupling of the motion analyzer to the circuit breaker operating rod.

D. **Cabinet Maintenance.** Maintenance of the equipment in the power circuit breaker cabinet.

E. **Circuit Breakers - High-Voltage.** High-voltage circuit breakers consist of oil, air, vacuum, or gas insulated circuit breakers, which operate in the range of above 15,000 volts

F. **Circuit Breakers - Low-Voltage.** Low voltage circuit breakers typically operate at 600 volts a.c. and below. There are three types:

1. **Molded Case Circuit Breakers.** Molded case circuit breakers are available in a wide range of ratings and are generally used for low-current, low energy power circuits. The breakers have self contained overcurrent trip elements.

2. **Insulated Case Circuit Breakers.** Insulated case circuit breakers are molded-case breakers using glass-reinforced insulating material for increased dielectric strength. In addition, they have push-to-open button, rotary-operated low-torque handles with an independent spring charged mechanism providing quick-make, quick break, protection.

3. **Heavy Duty Power Circuit Breakers.** Heavy duty power circuit breakers employ spring operated, stored energy mechanisms for quick-make, quick-break manual or electric operation. Generally, these breakers have draw-out

features whereby individual breakers can be deenergized for maintenance purposes.

G. **Circuit Breakers - Medium-Voltage.** Medium-voltage circuit breakers consist of air-magnetic circuit breakers (either of horizontal drawout type or vertical lift type), oil circuit breakers, and vacuum circuit breakers which operate in the range of 600 to 15,000 volts.

H. **Connections test.** Inspect the connections to the circuit breaker to determine that a good joint is present and that overheating is not occurring. If overheating is indicated by discoloration or signs of arcing, remove the connections and clean the connecting surfaces.

I. **Diagnostic testing.** Testing that includes breaker timing, power factor, contact impedance, strength of dielectric medium, and any other tests as deemed appropriate.

J. **Insulation resistance test**. Use a megger to perform tests between phases of opposite polarity and from current-carrying parts of the circuit breaker to ground. Also test between the line and load terminals with the breaker in the open position. Disconnect load and line conductors from the breaker during insulation resistance tests to prevent test measurements from including resistance of the attached circuit. Resistance values below 1 megohm are considered unsafe. Inspect the breaker for possible contamination on its surfaces.

K. **Mechanical operation.** Check the mechanical operation of the breaker by opening and closing the breaker several times.

L. **Millivolt drop test.** (Contact Resistance) A millivolt drop or similar tests can disclose abnormal conditions inside a breaker, such as eroded contacts, contaminated contacts, or loose internal connections. The millivolt drop test should be made at a nominal direct-current (dc) voltage recommended by the manufacturer, at 100 or 200 amperes for large breakers and at or below rating for smaller breakers. The millivolt drop is compared against manufacturer’s data for the breaker being tested. When manufacturer’s data does not exist, test breakers at or near nameplate value.

M. **Overload tripping test.** Verify proper action of the overload tripping components of the circuit breaker by applying 300 percent of the breaker-rated continuous current to each pole. The significant part of this test is the automatic opening of the circuit breaker, not tripping times. Trip time can be greatly affected by ambient and test conditions.

N. **Power factor test.** The testing of insulation to measure the power dissipated in watts to the product of the effective voltage and current in voltampheres using sinusoidal voltage and prescribed conditions.

O. **Reliability Centered Maintenance (RCM).** The assigning of value or importance to equipment to determine the maintenance priority of equipment to maintain the integrity and reliablilty of the power system and customer load.

4. IMPORTANCE OF ADEQUATE MAINTENANCE.

The maintenance of circuit breakers deserves special consideration because of their importance for routine switching and for protecting other equipment. Electric transmission system breakups and equipment destruction can occur if a circuit breaker fails to operate. Yet the need for maintenance of circuit breakers may not be obvious since they may remain idle, either open or closed, for long periods of time. Operating the breaker at least once a year re-applies lubrication to surfaces and verifies correct operation. RCM and predictive maintenance has modified or eliminated time based maintenance of tasks like internal breaker inspections or complete service. Breaker monitors or diagnostic testing flag when these tasks need to be performed.

5. SAFETY PRACTICES.

Maintenance procedures include the safety practices indicated in the latest revision of the PSSM. The following points are emphasized:

A. Ensure that the circuit breaker and its mechanism are disconnected from all electric power, primary and control voltage, before it is repaired.

B. Exhaust the pressure from the air receiver of any compressed air circuit breaker before it is repaired. Also, release the hydraulic pressure or the spring energy if applicable.

C. After the circuit breaker has been disconnected from the electrical power, attach the grounding leads properly before touching any of the circuit breaker parts that are normally energized.

6. LOCKOUT/TAGOUT.

Locking and tagging procedures for the deenergizing of electric energy sources for the purpose of performing maintenance on the power circuit breakers referred to in this chapter (which are used exclusively for purposes of power transmission and distribution) are addressed by Chapter 1 of the Power System Operations Manual. Required maintenance procedures for deenergizing and installing personal protective grounds on substation equipment are addressed by Chapter 1 of the Power System Maintenance Manual.

7. INSPECTION SCHEDULE FOR NEW BREAKERS.

A temporary schedule of frequent inspections is necessary after the erection of new equipment, the modification or modernization of old equipment, or the reapplication of old equipment under different conditions. The temporary schedule is required to correct internal defects which may appear in the first year of service and to correlate external check procedures with internal conditions as a basis for establishing predictive maintenance programs. If a circuit breaker shows no serious defects during early internal and external inspections, and no heavy interrupting duty is imposed, the following inspection schedule is recommended:

11 months after erection or before warrantee expires:	External inspection and checks to repair problems under warrantee. If no problems, perform regular maintenance. If there are problems, another inspection should be performed after 12 months; then return to the regular maintenance schedule.

8. INSPECTION SCHEDULE FOR EXISTING BREAKERS.

The inspection schedule should be based upon the maintenance intervals recommended in the *PSMM, Substation Maintenance Guidelines - Substations Chapter 13*. The suggested time required to perform these tests is listed in the *Substation Maintenance Productivity Review*.

With proper external checks, the expense, delay, and labor of internal inspections may be avoided without sacrificing dependability. Internal conditions can be determined through oil/sf-6 gas analysis, power factor testing, time travel testing, and the millivolt drop test.. Complete breaker maintenance should be performed only when the diagnostic testing dictates that it is necessary. **THERE WILL BE NO TIME BASED SCHEDULING FOR COMPLETE BREAKER SERVICE.**

9. FREQUENCY OF MAINTENANCE.

A. Conditions that Affect Maintenance. Conditions that cause increased wear and degrade performance which will the increase frequency of maintenance are:

1. High humidity and high ambient temperature;
2. Dusty or dirty atmosphere;
3. Corrosive atmosphere;
4. Frequent switching operations;
5. Frequent fault operations; and
6. Older equipment with records of historical failure.

A breaker should be inspected whenever it has interrupted current at or near its rated capacity

B. Maintenance of Low-Voltage Circuit Breakers. Depending on their service and operating conditions, low-voltage circuit breakers operating at 600 volts alternating voltage and below, should have maintenance performed annually.. The inspection schedule should be based upon the maintenance intervals recommended in the *PSMM,Substation Maintenance Guidelines - Substations Chapter 13*. Time intervals between diagnostic testing will depend on age of equipment, severity of operating conditions, and past history.

1. Maintenance of Molded Case Circuit Breakers [Below 110 Volts Alternating Current (AC)]. Molded case circuit breakers require little or no routine maintenance throughout their normal lifetimes.

2. Maintenance of Molded Case Circuit Breakers [Above 110 Volts Alternating Current (AC)]. The need for preventive maintenance will vary depending on operating conditions. Since accumulation of dust on the latch surfaces may affect the operation of the breaker, molded case circuit breakers should be exercised at least once per year.

C. Maintenance of Medium-Voltage Circuit Breakers. Medium-voltage circuit breakers, which operate in the range of 600 to 15,000 volts. Annual maintenance is required. The inspection schedule should be based upon the maintenance intervals recommended in the *PSMM, Substation Maintenance Guidelines - Substations*

Chapter13. Time intervals between diagnostic testing will depend on age of equipment, severity of operating conditions, and past history.

D. **Maintenance of High-voltage Circuit Breakers.** High-voltage circuit breakers consist of oil, vacuum, or gas insulated circuit breakers, which operate in the range above 15,000 volts. The inspection schedule should be based upon the maintenance intervals recommended in the *PSMM, Substation Maintenance Guidelines - Substations Chapter 13*. Time intervals between diagnostic testing will depend on age of equipment, severity of operating conditions, and past history.

10. ROUTINE MAINTENANCE PROCEDURES.

A. **Molded Case Routine Maintenance Procedures.** Routine maintenance tests enable personnel to determine if breakers are capable of performing their basic circuit protective functions. The following tests may be performed during routine maintenance to assure that the breakers are functional. All molded case breakers should be tested. Associated equipment must be removed from service These tests should be performed only on breakers and equipment that are deenergized.

1. Insulation resistance test.
2. Millivolt drop test.
3. Connections test.
4. Overload tripping test.
5. Mechanical operation.
6. Additional tests**.** Additional tests which may be performed include: steady-state and variable load tests to determine false tripping, test for time delay between fault and trip, and minimum tripping current.

B. **Air Circuit Breaker Maintenance Procedures.** The following suggestions are for use in conjunction with the manufacturer's instruction books for the maintenance of air circuit breakers.

1. Clean the insulating parts including the bushings.
2. Check the alignment and condition of movable and stationary contacts, and adjust them according to the manufacturer's data.
3. Inspect breaker operating mechanism for loose hardware and missing or broken cotter pins. Examine the cam, latch, and roller surfaces for damage or wear.
4. Check arc chutes and replace damaged parts.
5. Clean and lubricate the operating mechanism, and adjust it as described in the manufacturer's instruction book. If the operating mechanism cannot be brought within specified tolerances, it usually indicates excessive wear and the need for a complete overhaul.
6. After servicing the circuit breaker, verify that the contacts move to the fully opened and fully closed positions, free of friction or binding, and that electrical operation is functional.

C. **Oil Circuit Breaker Maintenance Procedures.** The following suggestions are for use in conjunction with the manufacturer's instruction books for the maintenance of oil circuit breakers.

1 . Check the condition, alignment, and adjustment of the contacts.
2 . Thoroughly clean and inspect the tank and other parts which have been in contact with the oil.
3 . Test the dielectric strength of the oil and power factor values. Filter or replace the oil if the dielectric strength is less than 25 kilovolts. The oil should be filtered or replaced whenever a visual inspection shows an excessive amount of carbon even if the dielectric strength is satisfactory.
4 . Check breaker and operating mechanisms for loose hardware and missing or broken cotter pins, retaining rings, etc.
5 . Adjust the breaker as indicated in the manufacturer's instruction book.
6 . Clean and lubricate the operating mechanism.
7 . Before replacing the tank, check to see that there is no friction or binding that would hinder the breaker's operation. Do not operate the breaker mechanism electrically without oil in the tank. These breakers can be manually adjusted, aligned, and operated. Operating a breaker electrically while it s not submerged in oil is destructive.
8 . When replacing the tank and refilling it with oil, be sure the gaskets are undamaged and all nuts and valves are tightened properly to prevent leakage.

D . **Sulfur Hexafluoride (Sf6) Gas Circuit Breaker Maintenance Procedures.** The following suggestions are for use in conjunction with the manufacturer's instruction books for the maintenance of sulfur hexafluoride (SF6) breakers.

1 . ***Consult Chapter 4 of the PSMM when working with SF6.***
2 . **Sf6 Maintenance Guidelines.** The equipment shall be serviced according to the manufacturer's instructions. SF6 gas should be tested every 3 months during the first year of service to determine the moisture content. SF6 gas should be tested whenever diagnostic testing is performed to determine moisture content and decomposition byproducts. Moisture content shall also be tested when gas is added. Moisture content should be less than 50 parts-per-million by volume (ppmv).

Employees shall not energize a section of the gas-insulated bus or piece of gas-insulated equipment if the SF6 gas density is less than 50 percent of nominal or if the moisture content of the gas exceeds 1000 (ppmv).

For internal inspections consult Appendix B Suggested Maintenance Procedure from *PSMM, "Sulfur Hexafluoride Gas Handling,"* Chapter 4, July 1994.

E . **Vacuum Circuit Breaker Maintenance Procedures.** Direct inspection of the primary contacts is not possible because they are enclose in vacuum containers. The operating mechanism is similar to the breakers discussed earlier and may be maintained in the same manner. The following two maintenance checks are suggested for primary contacts:

1 . Measuring the change in external shaft position after a period of use can indicate the extent of contact erosion. Consult the manufacturer's instruction book for information.

2 . Condition of the vacuum can be checked by a hi-pot test. Consult the manufacturer's instruction book. In general, internal conditions can be easily determined through power factor and millivolt drop tests. Use caution to avoid exceeding voltage and/or current ratings .

11. EXTERNAL INSPECTION GUIDELINES.

The following items should be included in an external inspection of a high-voltage breaker.

A . Visually inspect circuit breaker externals and the operating mechanism. Carefully examine tripping latches since small errors in adjustments, clearances, and roughness of the latching surfaces may cause the breaker to latch improperly or increase the force necessary to trip the breaker such that electrical tripping will not always be successful. Excessive opening spring pressure can cause excessive friction at the tripping latch and should be avoided. Also, some extra pressure against the tripping latch may be caused by the electromagnetic forces due to the flow of heavy shortcircuit currents through the breaker. Lubricate the bearing surfaces of the operating mechanism as recommended in the manufacturer's instruction book or modern lubrication guide. Avoid excessive lubrication because oily surfaces collect dust and get stiff in cold weather, resulting in excessive friction.

B . For oil breakers, check oil dielectric strength, power factor, acidity, and color. The dielectric strength must be maintained to prevent internal breakdown under voltage surges and to enable the interrupter to function properly since its action depends upon changing the internal arc path from a fair conductor to a good insulator in the short interval while the current is passing through zero. The manufacturer's instructions state the lowest allowable dielectric strength for the various circuit breakers. The dielectric strength should be maintained above 25 kilovolts even though some manufacturer's instructions allow 16 kilovolts.

If the oil is carbonized, filtering may remove the suspended particles, but the interrupters, bushings, etc., must be wiped clean. If the dielectric strength is lowered by moisture, inspect the fiber and wood parts, correct the source of the moisture, and dry the affected parts thoroughly before placing the breaker in service.

C . If possible, observe breaker operation under load.

D . Operate the breaker manually and electrically, and look for malfunctions. Determine the presence of excessive friction in the tripping mechanism and the margin of safety in the tripping function by testing the minimum voltage required to trip the breaker. This can be accomplished by connecting a switch and rheostat in series with the trip-coil circuit at the breaker (across the terminals to the remote control switch) and a voltmeter across the trip coil. Starting below 50 percent of rated trip coil voltage, gradually increase the voltage until the trip-coil plunger picks up and successfully trips the breaker. Make several trial tripping operations of the breaker, and record the minimum tripping voltage. Most breakers should trip at about 56 percent of rated trip-coil voltage. Measure the trip coil resistance and compare it with the factory test value to disclose shorted turns.

Most modern breakers have trip coils which will overheat or burn out if left energized for more than a short period. An auxiliary switch is used in series with the coil to open the circuit as soon as the breaker has opened. The auxiliary switch must be properly adjusted to successfully break the arc without damage to the contacts.

Also determine the minimum voltage that will close the breaker and the closing coil resistance.

E. Trip breaker from protective relays.

F. Check operating mechanism adjustments. Measure the mechanical clearances of the operating mechanism associated with each tank or pole. Appreciable variation between the clearance measured and the previous setting usually indicates mechanical trouble. Temperature and difference of temperature between parts of the mechanism affect the clearances. The manufacturer's recommended tolerances usually allow for these effects.

G. Power factor test the bushings and breaker.

H. Measure **millivolt drop** (contact resistance). If no foreign material is present, the contact resistance of high-pressure, butt-type contacts is practically independent of surface condition. Nevertheless, the measurement of the electrical resistance between external bushing terminals of each pole may be regarded as the final proof. An abnormal increase in the resistance of this circuit may indicate foreign material in the contacts, loose contact support, loose jumper, loose bushing connection, or corrosion. Any one of these may cause localized heating and deterioration.

Measure resistance of the main contact circuits with a portable double bridge (Kelvin) or a "Ductor." The breaker contacts should not be opened during this test because of possible damage to the test equipment. Compare resistance values to the manufacturer's values or to values found on a similar breaker; these values should not vary more than 25 percent between poles.

Exhibit 1 gives maximum contact resistances for typical classes of breakers.

I. Make time-travel or motion-analyzer records. Circuit breaker motion analyzers are portable devices designed to monitor the operation of power circuit breakers which permit mechanical coupling of the motion analyzer to the circuit breaker operating rod. These include high-voltage and extra-high-voltage dead tank and SF6 breakers, and low-voltage air and vacuum circuit breakers. Motion analyzers can provide graphic records of close or open initiation signals, contact closing or opening time with respect to initiation signals, contact movement and velocity, and contact bounce or rebound. The records obtainened not only indicate when mechanical problems are present, but also help isolate the cause of the problems. Obtain a motion-analyzer record on a breaker when it is first installed. This will provide a master record which can be filed and used for comparison with future maintenance checks. Tripping and closing voltages should be recorded on the master record so subsequent tests can be performed under comparable conditions.

Time-travel records are taken on the middle pole from the operating mechanism.

J. Check the air system on the pneumatic mechanism for leaks.

K. Check control wiring for loose connections.

L. Check the settings of compressor switches, low pressure alarm, and cut-off switches.

M. Inspect and check the operating mechanism. Lubricate all pins, bearings, and latches using the recommended lubricant.

12. INTERNAL INSPECTION GUIDELINES.

An internal inspection should include all items listed for an external inspection, plus the breaker tanks or contact heads should be opened. Inspect the contacts and interrupting parts.

Internal inspections will be performed as needed, determined by diagnostic testing, excessive operations, interrupting fault near rated fault interrupting capacity, abnormal sounds or behavior, manufacturer's I2t is reached, etc.

These guidelines are not intended to be a complete list of breaker maintenance items but are intended to provide an idea of the scope of each inspection. The checklist furnished by the manufacturer should be used for recording data during inspection and maintenance of each circuit breaker.

A. **Enclosed Space Entry.** Workers must adhere to enclosed space requirements outlined in WAPA Order 3790.1A.

B. **Typical Internal Breaker Problems.** The following difficulties should be looked for during internal breaker inspections.

1. The tendency for keys, bolts (especially fiber), cotter pins, and other items to loosen or become excessively worn and weakened.
2. The tendency for wood-operating rods, supports, or guides to loosen from clamps or mountings.
3. The tendency for carbon or sludge to form and accumulate in the interrupter or on bushings.
4. The tendency for the interrupter to flashover and rupture the static shield or resistor.
5. The tendency for interrupter parts or barriers to burn or erode.
6. The tendency for bushing gaskets to leak moisture into the breaker insulating material.
7. Cracks in any of the above parts

C. **Influence of Duty Imposed.**

1. **Influence Of Light Duty On Oil Circuit Breakers.** If the breaker has been energized on both sides, but the contacts are open, erosion in the form of irregular grooves (called tracking) may appear on the inner surface of the interrupter or shields due to electrostatic charging current. This is usually aggravated by a deposit of carbon sludge which has previously been generated by some interrupting operation. If the breaker has remained closed and carrying current, evidence of heating of the contacts may be found if the contact surfaces were not clean, have oxidized, or if the contact pressure was improper. Any shrinkage and loosening of wood or fiber parts (due to loss of absorbed

moisture into the dry oil) will take place following breaker installation, independent of breaker operation. However, mechanical operation, will make any loosening more evident. If possible, before inspection, open and close the breaker while energized. If this is not possible, additional information may be gained by operating the deenergized breaker several times, measuring the contact resistance of each pole before and after each operation.

2. **Influence Of Normal Duty.** The severity of duty imposed by load switching, line deenergizing, and fault interruptions depends upon the type of circuit breaker involved. In circuit breakers which employ an oil blast generated by the power arc, the interruption of low current faults or the interruption of line charging current may cause more deterioration than the interruption of high current faults because of low oil pressure. In some designs using this basic principle of interruption, distress at low interrupting duty is minimized by multiple breaks, rapid contact travel, and turbulence of the oil caused by movement of the contact and mechanism. In designs employing a mechanically driven piston to supplement the arc-driven oil blast, the performance is more uniform. Better performance is yielded by designs which depend upon a mechanically driven oil blast for arc interruption. In this type, contact erosion may appear only with heavy interruptions. The mechanical stresses that accompany heavy interruptions are always more severe.

   These variations of performance among various designs must be considered when evaluating the need for maintenance and performance of a breaker. Because of these variations, the practice of evaluating each fault interruption as equivalent to 100 no-load operations is approximate, although it may be a useful guide in the absence of other information.

3. **Influence Of Severe Duty.** Contact erosion and damage from severe mechanical stresses may occur during large fault interruptions. Reliable indication of the stress, which a circuit breaker is subjected to during fault interruptions, is obtained by automatic oscillograph records. Deterioration of the circuit breaker is proportional to the energy dissipated in the breaker during the interruption. The energy dissipated is proportional to the current and the duration of arcing, that is, the time from the moment the contacts part to current interruption. However, the oscillograph does not always record the moment contacts part, and it may be necessary to determine the parting from indicated relay time and the known time for breaker contacts to part. When automatic oscillograph records are available, they may be as useful in guiding oil circuit breaker maintenance as in showing relay and system performance.

   When automatic oscillographs are not available, an approximate indication of fault duty imposed on the circuit breakers may be obtained from relay targets and accompanying system conditions. All such data should be tabulated in the circuit breaker maintenance file.

13. GENERAL PAINTING CRITERIA.

This section is excerpted from Western's "Painting Specification;" further information can be obtained by referring to the paint specification available from Design at CSO (A3900). The standard color for outdoor electrical equipment, oil storage tanks, and other outdoor substation items is ANSI 70 (gray) with galvanized steel structures. This standard should be adhered to unless the design data clearly defines reasons for deviating. Deviations from this standard may be warranted when making an addition to an existing yard where:

1. The size of the addition is small in relation to the size of the existing yard that is to remain. However, this may not warrant deviating from the standard if the existing items will need repainting in the near future or if the existing painted items will fade such that a color match is not possible.

2. Forest Service, Bureau of Land Management (BLM), residential neighborhood, or other environmental concerns preclude adherence to the standard.

3. Major structural redesign would be required.

A. Painting.

1. **General.** Prepare surfaces and apply paints and protective coatings not included here according to the manufacturer's instructions.

2. **Delivery And Storage.** Deliver paint materials in sealed containers labeled with the manufacturer's name, type of paint, brand name, color designation, date of manufacturing, and instructions for mixing and reducing. Store paint materials as recommended by the manufacturer.

3. **Work Environment**. Provide ventilation, lighting, and necessary safety equipment for protecting workers during painting operations.

4. **Protection.** Protect nameplates, cover plates, and other surfaces from paint and damage. Repair damage resulting from inadequate or unsuitable protection. Furnish drop cloths, shields, or protective equipment to prevent spraying or droppings from fouling surfaces not being painted, including surfaces within storage and preparation areas.

5. **Manufacturers.** Manufacturers listed below have established a standard of quality:

   a. Keeler & Long, Incorporated, P.O. Box 460, Watertown, CT 06795.
   b. PPG Industries Incorporated, One PPG Place, Pittsburgh, PA 15272.
   c. Sherwin-Williams Company, 101 Prospect Avenue, Cleveland, OH 44115.
   d. Tnemec Company, P.O. Box 1749, Kansas City, MO 64141.

6. **Environmental Protection.** Precautions will be taken to avoid spills; to properly collect and dispose of waste thinners, solvents, paint, rags, and other wastes in accordance with regulations. Follow paint manufacturers label directions to ensure painting activities do not pollute the air, water, and soil.

B. Surface Preparation.

1. **General.** Prepare surface according to the manufacturer's technical information and as given in the following subsections.

2. **Solvent Cleaning.** Remove oil and grease from surfaces as follows:

   a. Wipe or scrub surfaces with solvent-wet cloths or brushes. For final wiping, use clean solvent and clean cloths or brushes. Solvents not regulated as hazardous waste after use are recommended so as to reduce disposal costs and potential health, safety, and environmental damage. Non-hazardous solvents may produce hazardous waste after use if the solvent picks up regulated substances during use. Procedures must be used such that solvent rinsate is collected tested, and disposed of properly.

   b. Spray surfaces with solvent. For final spraying, use clean solvent.

   c. Steam clean, using detergents or cleaners followed by steam or fresh water wash. Steam cleaning without additives may be used to remove chalk from surfaces not contaminated with oil or grease.

3. **Equipment And Metalwork.** After solvent cleaning, prepare surfaces as follows:

   a. Lightly sand surfaces composed of weathered, gloss, or semigloss paint. Paint surfaces must be tested for lead and other substances which may be harmful to human health and the environment. Paint dust and spent blast media must be handled and disposed of according to applicable regulation and health and safety guidelines

   b. Clean surfaces with loose paint and other foreign matter by hand tool methods conforming to SSPC-SP2 followed by, if required, commercial-grade sandblasting conforming to SSPC SP6.

   c. Clean unpainted surfaces by commercial-grade sandblasting conforming to SSPC-SP6.

   d. Clean all surfaces with solvent.

C. Paint Systems.

1. **General.** Selected paint systems for any particular item shall consist of primer or tie coat and finish coats from the same manufacturer.

2. **Galvanized Surfaces.** To repair galvanized surfaces not required to have a finish coat, use a minimum 3.0 mils dry film thickness and equal to one of the following:

   a. Keeler & Long, Incorporated, “No. 01Q0 Kolor-Zinc Primer.”
   b. PPG Industries, Incorporated, “Metalhide 1001 Inorganic Zinc Rich Primer.”
   c. Sherwin-Williams Company, “Zinc Clad I B69A56.”
   d. Tnemec Company, “90E-92 Tnemec-Zinc.”

3. **Existing Outdoor Electrical Equipment.** For existing outdoor electrical equipment, use paint equal to one of the following:

   a. Keeler & Long, Incorporated:
      1. First and Second Primer Coat: "No. 9G00 Kolor-Quick White Primer," 2.0 to 4.0 mils dry film thickness per coat for ferrous metal surfaces; or "No. 040 TriPolar White."
      2. Primer," .5 to 3.5 mils dry film thickness per coat for galvanized surfaces.
      3. Finish Coat: "No. P-1-6792 or P-Series Poly-Silicone Enamel, Color Sky Gray, Gloss," 1.5 to 2.5 mils dry film thickness for ferrous metal or galvanized surfaces.

   b. Tnemec Company:
      1. Primer Coat: "37-77W Chem-Primer, Color White," 2.0 to 3.5 mils dry film thickness for ferrous metal or galvanized surfaces.
      2. Tie Coat: "23-BJ45 Light Gray, 23-Series Enduratone, Semigloss," 1.5 to 3.0 mils dry film thickness for ferrous metal or galvanized surfaces.
      3. Finish Coat: "82-BJ45 Light Gray, 82-Series Silicone-Alkyd, Gloss," 1.0 to 2.0 mils dry film thickness for ferrous metal or galvanized surfaces.

   Repair damaged areas of the manufacturer's standard permanent paint system before applying finish coats. Paint outdoor electrical equipment equal to one of the following:

   c. Keeler & Long, Incorporated:

      1. First and Second Finish Coats: "No. P-Series Poly-Silicone Enamel, Gloss," 1.5 to 2.5 mils dry film thickness per coat.

   d. Tnemec Company:

      1. First and Second Finish Coats: "82-Series Silicone-Alkyd, Gloss," 1.0 to 2.0 mils dry film thickness per coat.

D. Color Schedule.

1. **General.** The color of finish coats of paint not specified in the "Paint Systems" section shall be as specified in the following subsections.

2. **Outdoor Electrical Equipment.** The specified colors refer to the Keeler & Long, Incorporated, numbering system and are for color match only.

   a. Power Circuit Breakers, Dead-tank Type:
      1. Tanks, interphase piping, structural bases, valves, bushing flanges, and cabinets: Color No. (Billings, Boulder City, Loveland) "3578 Desert Beige," (Salt Lake City) "4938 Shell Tint," (Sacramento) "8591 Off-White."
      2. Bushing caps and emergency trip levers: Color No. (Billings,

Boulder City, Loveland, Salt Lake City) “8165 Airway Orange,” (Sacramento) “1105 Dark Red.”

b. Power Circuit Breakers, Live-Tank Type:

1. Any painted portion of columns, interrupter heads, and cabinets: Color No. (Billings, Boulder City, Loveland) “3578 Desert Beige,” (Salt Lake City) “4938 Shell Tint,” (Sacramento)“8591 Off White.”

14. REFERENCES.

A. A.“Maintenance of Power Circuit Breakers,” **Power O&M Bulletin**, No. 28, Bureau of Reclamation.

B. Painting Specification, **Substation Specification**, Division 7, Western Area Power Administration, December 16, 1987.

C. **Power System Safety Manual**, Western Area Power Administration, United States Department of Energy, latest revision.

D. **Substation Maintenance Productivity Review**, Western Area Power Administration, United States Department of Energy, April 1988.

E. Sulfur Hexafluoride Gas Handling,” **Power System Maintenance Manual**, Chapter 4, July 1994.

F. Standard Maintenance Guidelines - Substations” **Power System Maintenance Manual**, Chapter 13, March, 1992.

G. **Enclosed Space Entry.** WAPA Order 3790.1A

H. **Lubrication Guide of the Doble Circuit Breaker Committee**, September 1997

Exhibit 1. Maximum Contact Resistance

Air/Gas/Vacuum Circuit Breakers			Oil Circuit Breakers		
kV	Amperes	Micro-ohm	kV	Amperes	Micro-ohm
	12002000	1005050	7.215	600	300
				1200	150
				2000	75
				4000	40
			23-24	ALL	500
			46	ALL	700
			69	600	500
				1200	500
				2000	100
			115-230	ALL	800
			345	ALL	250